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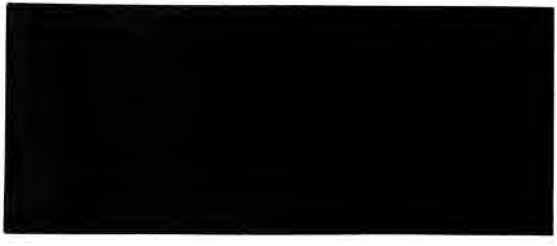
Kenan E. Sahin*

468-70 June, 1970



DETECTION OF ANGULAR ORIENTATION OF A LINE USING A HEXAGONAL SELCUK NETWORK

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Overview

In a previous paper*,** Selcuk networks of various configurations were discussed in great detail. There it was shown how communication without addressing could be achieved. This paper will very briefly review non-addressed communication capability for the "hexagonal class K" type of a network and will show that such a capability can be exploited to recognize the angular orientation of a line of arbitrary thickness and length.***

Hexagonal Class K Network

As in all Selcuk networks, in class K network, too, channels are unidirectional. Modules and channels are so arranged that a connected graph composed of repeated hexagons is formed. In each module, the channels alternate in direction, i.e. when one channel is directed to the module the next one is directed away from that particular module as follows:

*Sahin, Kenan E., "Directed Intermodular Communication without Addressing in Unidirectional Planar Arrays," Working Paper 373-69, Sloan School of Management, MIT, 1969.

**Sahin, Kenan E., Directed Intermodular Communication without Addressing in Unidirectional Planar Arrays, Unpublished Ph.D. thesis, Sloan School of Management, MIT, Cambridge, 1969.

***Patent is pending for non-addressed communication methods as well as the recognition methods described here.

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The resulting connected graph has flow lines oriented in three directions only. Figure 1 depicts a hexagonal class K network.

Each module is assumed to have limited memory and limited logic capability. The appropriate sizes depend on the intended application.

Non-addressed Response Routing

Suppose a module wants information on a particular topic. It does not know which one of the modules in the network might have this information. The main concern is not really determining the location of the information housing module but the recovery of that information.

In such a problem situation where identity is not important, non-addressed communication is quite appropriate if it can be achieved with reasonable ease. Sahin* demonstrated that such communication is quite feasible. Basically the information-seeking module emits a general message that is an information request which is propagated on all outgoing channels. Another module upon first receiving the request transmits it on all outgoing channels. In this fashion request propagation is accomplished in time, t, which is proportional to $\sqrt{N}$ where N is the number of total modules in the network. Each module remembers on which channel(s) the request first arrived. Call this request arrival configuration.

If upon receiving a request, a module wants to respond, it sends

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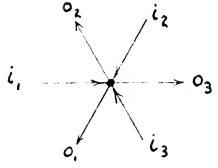
*Sahin, op. cit.

the response along a channel determined by a decision rule based solely on the request arrival configuration of that module. The module receiving the response routes it exactly the same way. When the decision rules are appropriately chosen, the response travels to the source of the request through a reasonably short path and without falling into cycles.

Let us arbitrarily label in a clock-wise fashion the channels of a hexagonal class K module as follows:



i_1, i_2, i_3 are the input channels and 0_1, 0_2, 0_3 are the output channels. Then the response routing rule for this type of module becomes:

request arrival configuration	response route
i_1	0_1
i_2	0_2
i_3	0_3
i_1, i_2	0_2
i_1, i_3	0_1
i_2, i_3	0_3

Examination of the class K network will reveal that requests can arrive simultaneously at most on two channels. Consequently the rules extend up to two simultaneous arrivals, e.g. i_1, i_2 which implies 0_2 as the response route.

Figure 1 shows propagation pattern of a request and how the response from a module is routed. The reader can check the response path using the above-described decision rules. He can also pick another module and using the rules assure himself that a response from that module will also reach the source.

It is to be noted that the rules are strictly local, that is each module applies them to its own routing, independently of the decisions of other modules, and without the influence of a central coordinator. Herein lies the uniqueness of Selcuk networks.

Adapting the Class K Network to Angle Recognition

In order to be used in recognition applications, we shall assume that each module of a K-type network either contains or is connected to a light sensitive device such as a photoelectric cell. In this manner when an image is projected upon the array of light-sensitive devices, the devices within the boundaries of the image are activated and so are the modules connected to those devices.

Examination of Figure 2 will reveal that the three outgoing channels define three regions such that in each region the request first arrival configurations are the same. It will also be noticed that if we were to

let the corner module A be the request propagator the entire network of Figure 2 would have a configuration like that of region one. Corner B would result in a configuration like that of region II and corner C like that of region III.

In the network for recognition applications only the corner modules A,B,C will be allowed to emit general messages. And when one of the corners starts a request (general message), the following rules will be observed by the modules of the network:

1) When a request (general message) arrives, if a module is quiescent (i.e. not within the boundaries of the image) it transmits the general message intact on all outgoing channels.

2) In the K network, when only the corners are used to initiate the general messages, the modules within the boundaries of the network will first receive the general message simultaneously on two channels.

   If a module is turned on (i.e. it is within the image) and if uncoded general messages arrive on two channels simultaneously, the general message is coded, for example, by complementing it and the coded general message is transmitted out on all outgoing channels.*

   Immediately afterwards a response is started which by rules explained before is routed to the corner which had started the general message.

   If a turned-on module receives an uncoded general message on one channel and coded message on another channel or if it receives coded general messages on two channels, then a coded general message is propagated on all outgoing channels; however a response is NOT sent.

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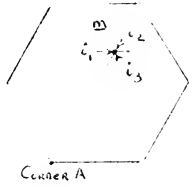
*Coding simply indicates that the module which is passing on the general message is turned-on, i.e. it is within the image.

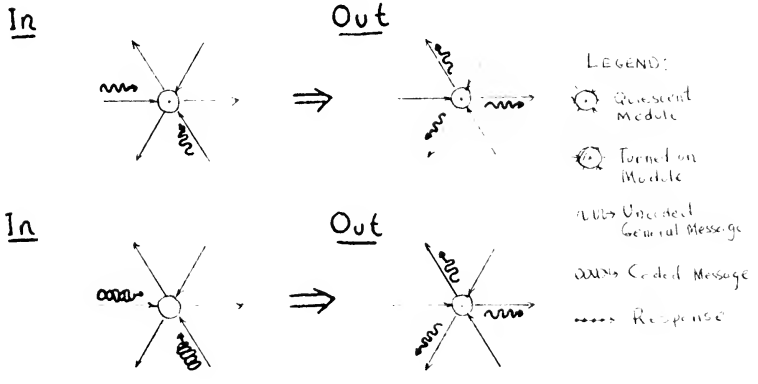
3) If a coded general message arrives at a quiescent module, the general message is uncoded and then propagated.

These rules can be explained diagramatically too. Consider a module m somewhere in the network and the corner A

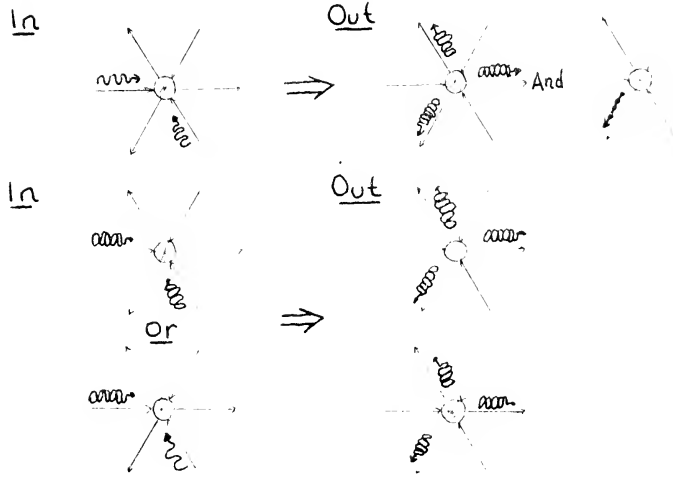


As referring to Figure 2 will also show, the general message will arrive on i_1 and i_3. Therefore we can consider m only as all other non-boundary modules will have the same general message arrival channels.

Case a: Assume m is not turned-on, i.e. it is not within the image



Case b: m is turned on, i.e. it is within the image boundary



Determination of Angular Orientation

Having explained the modified rules of operation in the hexagonal class K network we can now turn to exploring how these modifications permit the recognition of angular orientations.

Referring to Figure 3, consider corner A and line L_1. After a general message starting from A spreads to the network, only module a_1 will send a response to A, in accordance with the rules stated earlier. This will be so no matter how long or wide the line is, provided it is within the network.*

*Also the line must be wider and longer than two modules.

However when line L_2 is considered, it will be seen that there will be multiple responses, i.e., from a_1', a_2', a_3' etc. Increasing the width of the line will not increase the number of responses, but increasing the length will do so.

The only difference between lines L^1 and L^2 is their angular orientation. By examining the figure, it will be seen that the general message emanating from corner A will result in multiple responses only when the angle of a line, θ, is between 0° and 60° with respect to the horizontal.

When multiple responses are received at A it is thus known that:

$$0^o < \theta < + 60^o$$

Similarly corner B is sensitive (i.e., receives multiple responses to a general message it emits) to θ when

$$-60^o < \theta < 0^o$$

and corner C detects θ when

$$-120^o < \theta < -60$$

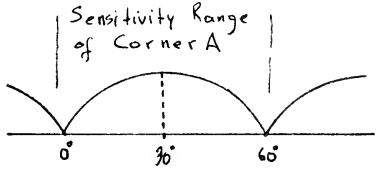
or

$$60^o < \theta < 120$$

Whatever the angular orientation, exactly one of the corners will be activated by multiple responses except when $\theta = 0^o$, 60°, -60°, in which case all three corners will receive a single response and therefore will not be activated.

Detection of Angles within the 60° Range

As it is displayed in Figure , when the angular orientation of a line changes the number of responses to the corner in whose sensitivity range θ falls, will increase until θ reaches the midpoint of the sensitivity range. Assume that in the first pass, corner A was activated and hence θ is now known to be between 0° and 60°. Let us divide this sensitivity range of 60° into two as follows:



If the image on the network is rotated by 30° one of three things will happen:

a) The same corner will again be activated in which case the original angle must be between 0° and 30°.

b) The next corner will be activated in which case

$$30^{o} < \theta < 60^{o}$$

c) None of the corners will be activated in which case

$$\theta = 30^{o}$$

The scheme can be repeated this time with a 15° rotation to determine θ with an accuracy of 15° and so on.

General Comments and Conclusion

It is doubtful that the class K network's angle determination could be of any practical use. Clearly more efficient schemes do exist for determining angular orientations of arbitrary lines. However it will be shown in a later paper that with basically the procedure described here, the class K network can be used to differentiate between triangles, parallelograms and circles of arbitrary sizes and orientations.

It is the method and not the immediate practical significance that appears interesting to the author. An analogy can be made with the calculator and the computer. Both can add. The strength of the computer is not that it can accomplish a task achieved much more easily by the calculator. The strength is in the method of achieving that task. The superiority of the computer is realized when that method is used in different and more complex tasks.

Similarly, although with conventional methods angles can be much more readily detected or circles and tetrahedra recognized, it is the belief of the author that the method described in this paper is worthwhile for research because of its promise for more complex tasks.

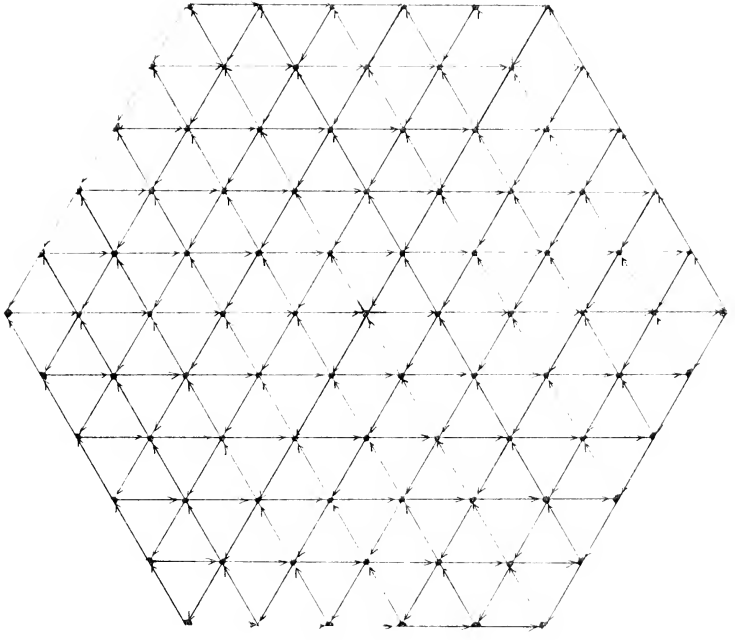


Figure 1

Hexagonal Class K Network

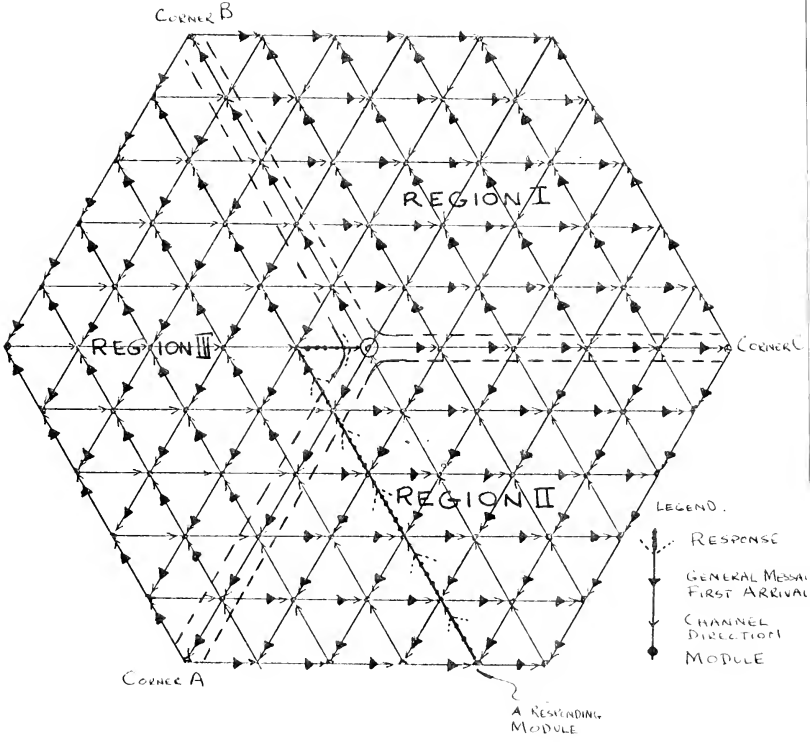


Figure 2

Propagdtion Pattern of a Request (General Message) and the Path of a Response. The Central Module Emits the Request.

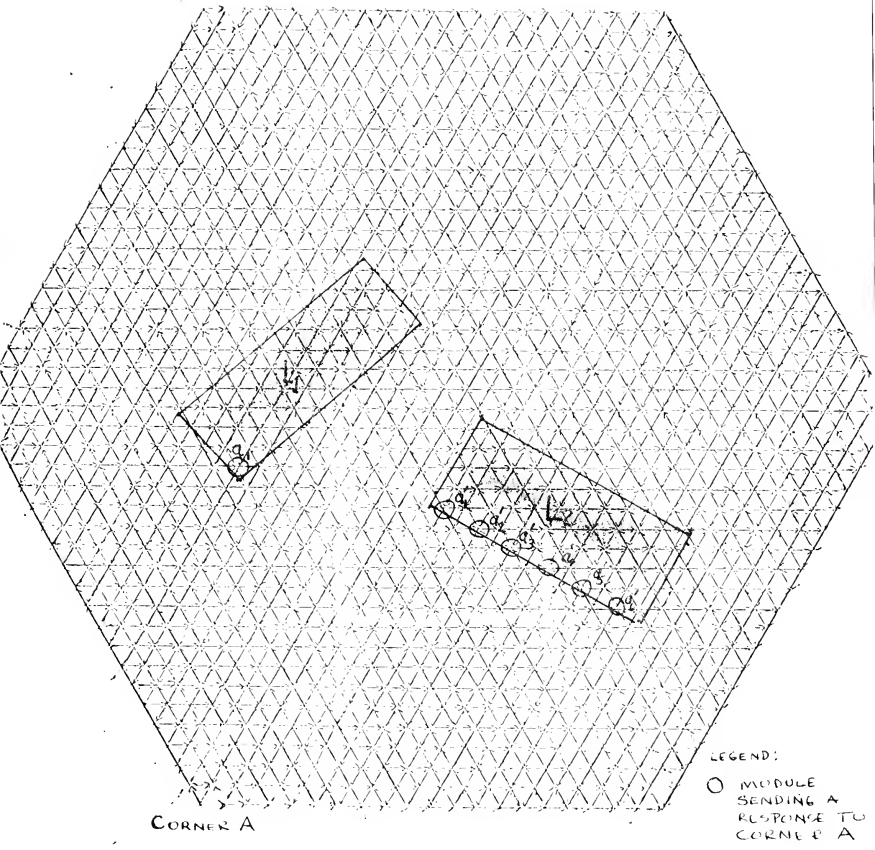


Figure 3

Responses to General Message from Corner A When Line L_1 is Imposed and When Line L_2 is Imposed. General Message First Arrivals are not Shown.

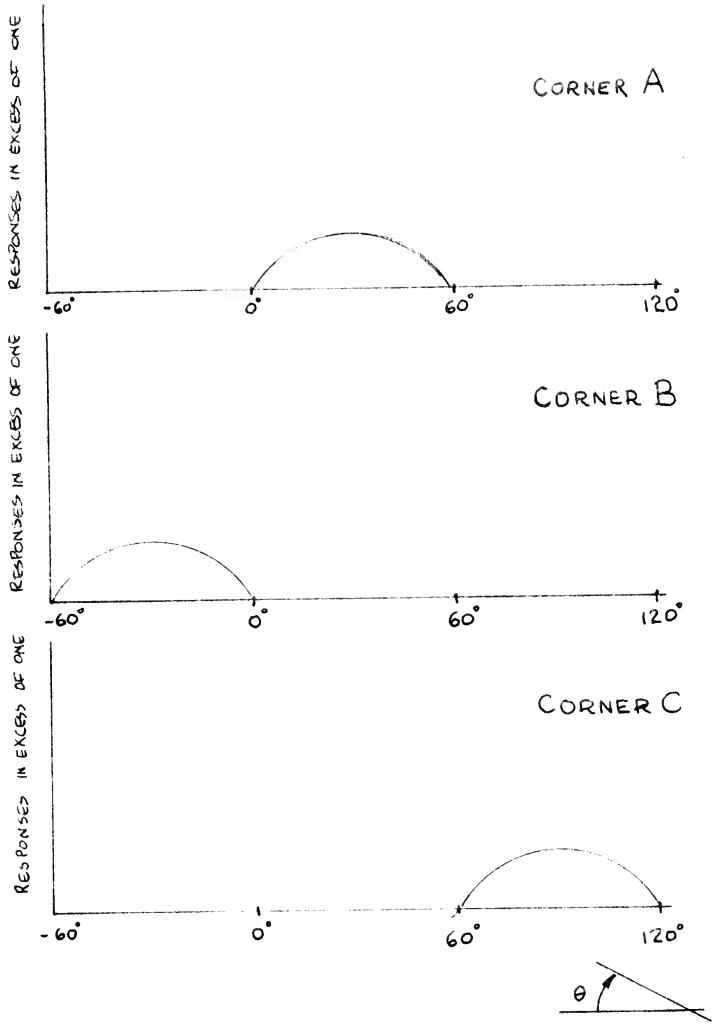


Figure 4

Sensitivity Ranges of Corners A, B, and C. Angles are with Respect to the Horizontal.

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